

Demand Activated Manufacturing Architecture

# Pipeline Analysis Guide for the U.S. Integrated Textile Complex

# **The Los Alamos DAMA Project Team** Compiled by Thomas L. Norris

Technology and Safety Assessment Division







### The Los Alamos DAMA Project Team:

Kathy Burris, Charu Chandra, Joe Fasel, Johnell Gonzales, Joe Jackson, Anthony Nastasi, Tom Norris, Rob Oakes, Jim Ostic, and Dennis Powell

This guide was prepared under the direction of Tom Norris with editing by Ann Mauzy, document design by Gloria Sharp and Annie Loweree, and graphics assistance by Anita Flores.

This report was prepared by Los Alamos National Laboratory as part of the DAMA Enterprise Modeling and Simulation Task.

For copies of this document, contact

James K. Ostic, Los Alamos National Laboratory, (505) 667-3941 or

DAMA Project office, TC², (919) 380-2184.

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. All company names, logos, and products mentioned herein are registered trademarks of their respective companies. Reference to any specific company or product is not to be contructed as an endorsement of said company or product by the Regents of the University of California, the United States, the U.S. Department of Energy, nor any of their employees.

# **Table of Contents**

Table 5-1. Example of Goals, Policies, and Objectives	9
Tables	
Figure 6-1. Network Diagram of Pipeline Activities	10
Figure 5-5. Typical Process Activities	
Figure 5-4. Typical Business and Information Flows	
Figure 5-3. Example Supply-Chain Enterprise Work Design and Methods	
Information, and Control Flows	
Figure 5-2. Example of Activities in a Process System along with Associated Material,	
Figure 5-1. Example of Level 2 Business Activities in the Textile Pipeline	6
throughput time by 50% and to reduce inventories	5
Figure 4-1. For the DAMA pilot project, we investigated ways to reduce product	
Figure 3-1. Pipeline Analysis Process	4
Figure 2-3. Levels of Business Decomposition	
Figure 2-2. Mail Order Catalog Pipeline Options "To-Be" Business Functions	
Figure 2-1. Manufacturing Processes for the Apparel Pipeline	2
Figure 1-1. Competitive Advantage of "To-Be" Pipeline	1
Figures	
13. Glossary of Terms	14
12. References	
11. For Further Reading	
10. Step 7. Recommendations for Implementation	
9. Step 6. Requirements Met?	
8. Step 5. System Performance Analysis	
7. Step 4. Requirements Met?	
6.2 System Structure and Flow Analysis	
6.1 System Component Analysis	
6. Step 3. System Engineering and Analysis	
5.2 System Flow-charting	
5.1 System Component Description	
5. Step 2. Detailed Description of "As-Is" System	
4. Step 1. Requirements Analysis	
3. Overview of Analysis Steps	
2. Description of a Pipeline	1
1. Introduction	1

#### 1. Introduction

The United States Integrated Textile Complex (USITC) is facing stiff competitive pressure in the global marketplace for textile and apparel goods. For example, offshore apparel producers manufacture roughly one-half of the U.S. retail apparel market. Imports of textile and apparel goods are the fourth largest import category, accounting for a higher value than crude oil and natural gas. The USITC is a supply chain of fiber, textile, apparel, and retail companies who partner to manufacture and distribute apparel goods. Pipeline analysis is directed to increasing industrial competitiveness by reducing product throughput time, lead time, stock-outs, removal of non-value added activities, etc. resulting in increased market share and profit margins. As such, the American Textile Partnership (AMTEX<sup>TM</sup>) is supporting development and transfer of methods for pipeline analysis.

"The goal of The AMTEX Partnership is to strengthen the competitiveness of the integrated U. S. textile industry-including the fiber, textile, apparel, and fabricated product sectors. AMTEX is a collaborative research and development program among the industry, the Department of Energy, the DOE laboratories, other federal agencies, and universities." (1)

Pipeline analysis examines ways to improve interactions and linkages between supply chain members where the pipeline includes the manufacturing and sales businesses from the raw materials to the sale of goods to the customer. The goal of the analysis is to identify and quantify changes resulting in increased competitiveness through coordination of supply chain members (Figure 1-1). This coordination emphasis builds upon lessons learned in "quick response" studies of the textile industry.

This guide provides an overview of what a pipeline is and how it can be decomposed into its parts for analysis. It then discusses the steps of pipeline analysis. This guide does not include all possible approaches to increasing competitiveness within the pipeline but focuses primarily on the approaches developed for the AMTEX pilot project.

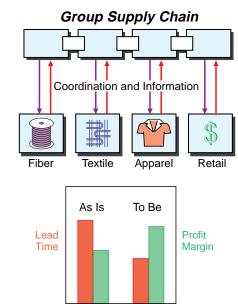


Figure 1-1. Competitive Advantage of "To-Be" Pipeline.

# 2. Description of a Pipeline

A typical supply-chain pipeline system as it exists today is a loosely integrated collection of businesses. Whether or not a supply chain pipeline is formally organized, every supply chain behaves as a system. Many times this system has undesired performance characteristics, such as delays in delivery, high inventory, or the inability to respond rapidly to changing market demands. Before we attempt to reconstruct the pipeline to remove these characteristics, it is necessary to understand the current structure of the pipeline.

Figure 2-1 is a graphic representation of the processes for a mail order catalog pipeline as it would exist today. One of the key features of this pipeline is the lack of coordination and control between the various members of the pipeline.

<sup>(1)</sup>Further information on the AMTEX project may be obtained on the Web at (http://cbmnt1.energylan.sandia.gov/amtexwww/amtex.html). For the DAMA project see (http://dama.tc2.com/) and (http://dama.tis.llnl.gov/).

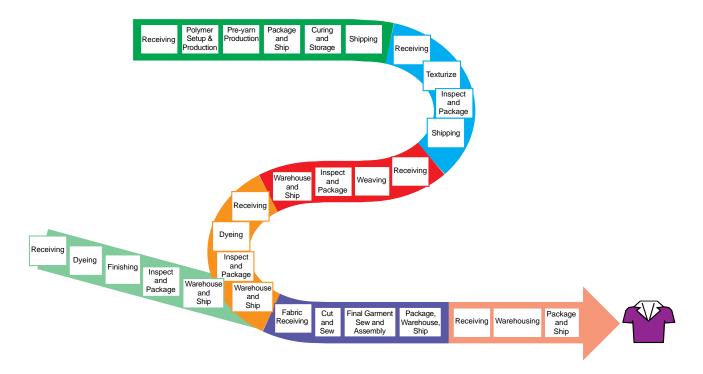


Figure 2-1. Manufacturing Processes for the Apparel Pipeline

There is only limited information passed between the members, e.g., sales and forecast projections and delivery of the ordered goods. At this level of coordination it is difficult for the competitiveness of this pipeline to increase significantly.

Pipeline analysis starts at the business function level and then begins to "reconstruct" the pipeline to improve performance and competitiveness. Even at the business function representation of the pipeline, a number of options exist for pipeline reconstruction. In Figure 2-2, the "as-is" pipeline has been reconfigured to include just-intime (JIT) manufacturing and to eliminate the inventory held at the catalog retailer so that the apparel manufacturer is now shipping directly to the final customers. Although these changes look promising to the overall competitiveness of the pipeline, there are consequences and implementation issues from this reconstruction that are not obvious. For better understanding of any pro-

posed changes to the "to-be" pipeline, we must thoroughly decompose it and understand the system behavior through the approach described in this guide.

The hierarchical system decomposition technique is used to understand the "as-is" and the "to-be" pipelines. At the initial stages of the analysis, the resolution of the system, i.e., the level of detail of each of the system components and flows, is kept to a fairly high level. A preliminary analysis is helpful to help set the boundaries, metrics, and constraints for the more detailed analysis to come. The goal here is to be sure the problem is well defined and that all the participants are in agreement.

In hierarchical decomposition (Figure 2-3), the topmost layer represents information flow in the enterprise. The next layer represents business flows in the enterprise. These are the main business functions. The following layer represents process flow in the enterprise.

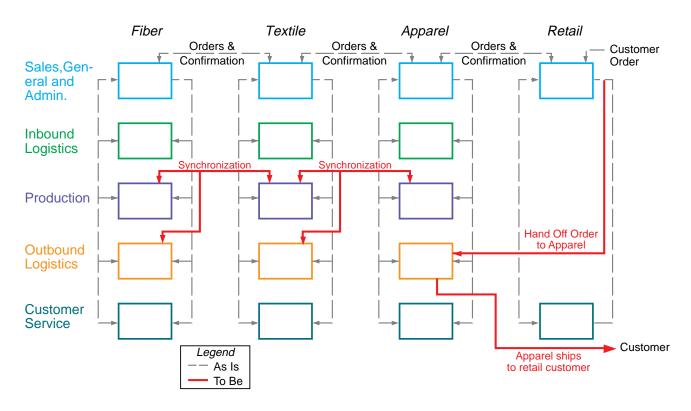


Figure 2-2. Mail Order Catalog Pipeline Options "To-Be" Business Functions. The dotted line shows the information and control flows in the "as-is" system. The solid line shows possible control and information flow for a more coordinated and flexible pipeline.

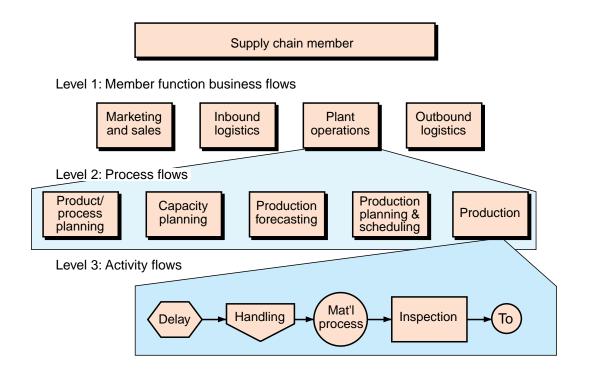


Figure 2-3. Levels of Business Decomposition.

# 3. Overview of Analysis Steps

The methodology for pipeline analysis consists of a systematic approach to the analysis of the current pipeline. The steps are shown schematically in Figure 3-1. Each step is briefly described below to provide an overview of the analytical process.

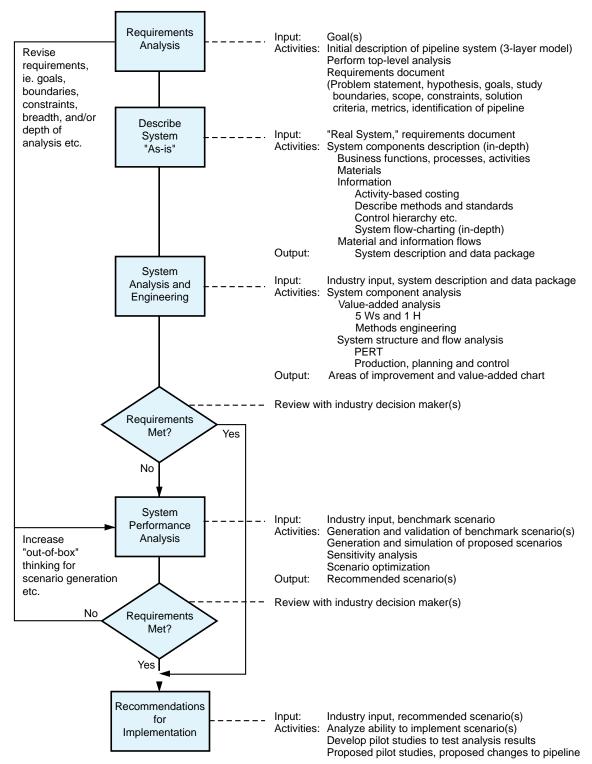


Figure 3-1. Pipeline Analysis Process

# 4. Step 1. Requirements Analysis

The first step is to have a clear definition of what the problem is with the current configuration of the pipeline and then to have a general hypothesis as to what might be improved in the pipeline to solve the problem. Both the problem and hypothesis are not fixed and can be modified during the analysis process as additional information and understanding are gained. The reason for clearly stating the problem is to focus the analysis and the data collection process on information necessary for possible pipeline improvements. The goal is to identify a clear problem that needs a solution and clear metrics to determine whether or not a solution has been found.



Figure 4-1. For the DAMA pilot project, we investigated ways to reduce product throughput time by 50% and to reduce inventories.

The parts of a requirements analysis are as follows:

- Identify top-level goals for the project.
- Clearly state and document the problem.
- Generate a testable hypothesis to solve the problem statement, and address the goals of the project.
- Prepare a top-level system description of the pipeline. This will aid in completing the other parts of the requirements analysis.

- Identify the boundaries of the study such as the companies and processes to be included in the study and the types of products, i.e., how many stock-keeping units (SKUs), will be investigated.
- Identify any constraints for the analysis, i.e., is the resolution of the system model at the business function level, process or activity level, or some combination?
- Determine the metrics that will be used to measure the performance of the proposed solutions against the problem, such as the total cost to produce product, throughput time, customer service level, stock-outs, the level of excess inventory, etc.
- Determine the assumptions in the analysis, e.g.,
  - Treating one of the companies or processes as a "black box" because it is believed it is not a major factor in solving the problem.
  - Treat all times deterministically on the assumption that taking into account the statistical variation of the time for a process is not critical to the results.

The final output will be a requirements document that delineates the work to be performed during the analysis and is an excellent tool to focus the pipeline analysis team on the issues of industrial concern.

# 5. Step 2. Detailed Description of "As-Is" System

#### **5.1 System Component Description**

The task is to break down each of the sector components, previously outlined in Step 1, into greater resolution. The enhanced resolution of the component is needed to provide sufficient detail and fidelity to represent the real-world situation for analysis.

- First, decompose business units in the supply chain into their respective processes and activities (Figure 5-1). Identify as "black boxes" those business units not to be analyzed in detail but still needed to complete the analysis of the pipeline.
- Identify the inputs, outputs, and attributes for each business process that may be relevant to the analysis. Figure 5-2 is an example of what each of these factors represents. For each process, determine which of these factors may be necessary for the analysis, and initially collect data only on the relevant factors.

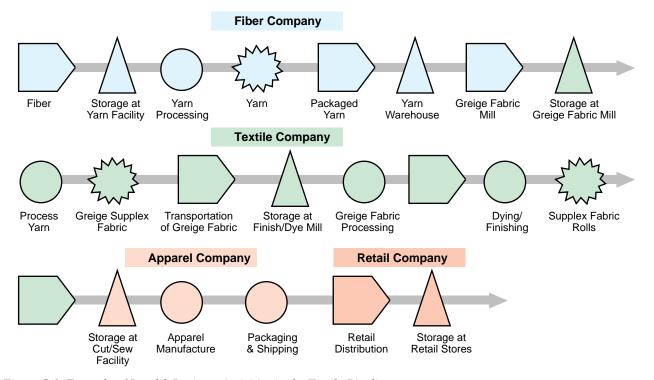


Figure 5-1. Example of Level 2 Business Activities in the Textile Pipeline.

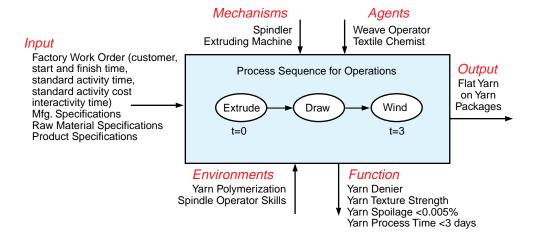


Figure 5-2. Example of Activities in a Process System along with Associated Material, Information, and Control Flows.

- For each process, collect the various cost and time data along with other pertinent information that may be of use in understanding the constraints on the process and thus may be modifiable to improve the system.
- Identify major activities within each business process. A recommended approach is to break each process into relatively large chunks of activities, at a level for which cost, time, and other data are available, but without trying to decompose the business process into minute activities unless that is necessary to solve the problem.
- Identify work design, methods, and standards. In this activity, relationships between methods, time standards, and costs of the operation are documented to understand the relationships. (Figure 5-3)
- Use activity-based costing to identify the system cost drivers. Activity-based costing is an accounting method that more accurately reflects the costs associated with the production of each product by identifying the sources of overhead and other indirect costs into the specific sources of these costs, in addition to a breakout of direct costs of manufacturing. Within this framework it is easier to see the origin of costs and thus target areas for change because it traces costs to a particular cost-adding activity.

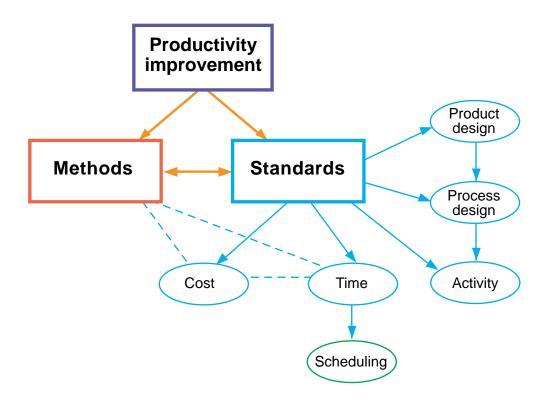


Figure 5-3. Example Supply-Chain Enterprise Work Design and Methods.

#### 5.2 System Flow-charting.

- Identify and trace major business process flows (Figure 5-4) within each business unit, e.g., marketing, sales, inbound logistics, scheduling, production, storage, outbound logistics, etc.
- For each business process trace the activities identified in Section 5.1 that make up that process (Figure 5-5).
- Identify member-level, i.e. individual company, goals, policies and/or objectives. Identify and trace business unit goals, policies, and objectives to each process within a business unit and determine how they are implemented within the process (i.e., tactical analysis) and how they are linked (Table 5-1).

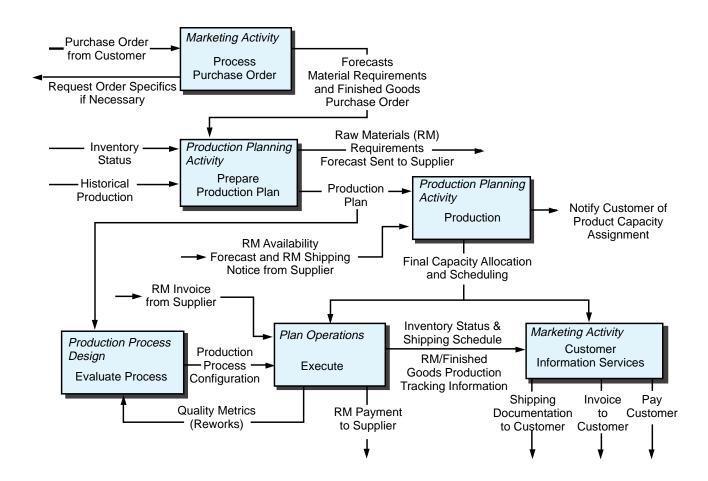


Figure 5-4. Typical Business and Information Flows. The flow chart shows many of the information and control flows between business functions in a manufacturing company.

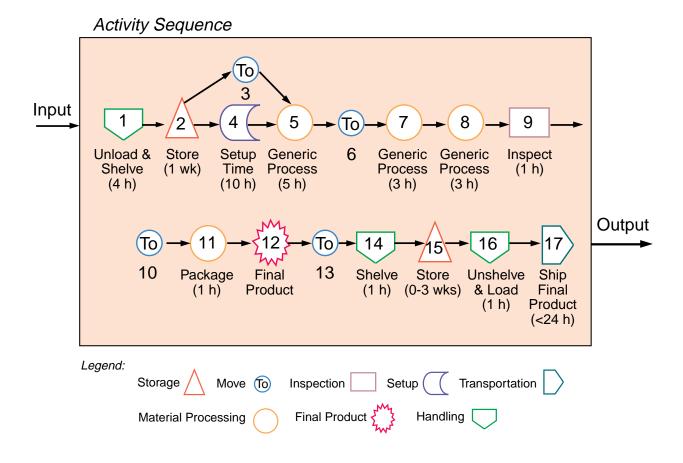


Figure 5-5. Typical Process Activities. Each process can be disaggregated into activities. The activity-level description may be needed to obtain data and to understand the process structure so that improvements may be investigated.

Table 5-1. Example of Goals, Policies, and Objectives.

	Objective(s)	Policy(ies)	Goal(s)
Marketing	Maximize customer service	Implement a procure-to- stock policy	Achieve a x% order-fill- rate within t days of order processing
Procurement Planning	Maximize inventory turns	Implement a JIT procurement policy	Achieve k inventory turns
Warehouse Operations	Minimize distribution costs	Implement a quick response shipment policy	Achieve a s% shipment-fill-rate of within t hours of order

# **6. Step 3. System Engineering and Analysis**

For each section in Step 3, a number of analytical tools are described. Which tools are used depends on the particular problem.

### **6.1 System Component Analysis**

- Value engineering. System analysis in this activity seeks to identify ways to eliminate a process that does not add value to the product (Porter, 1985)
- Methods engineering. Methods engineering investigates an activity that seems to be inefficient and identifies improvements or a new task for methods development. The basic steps are as follows (Schonberger and Knod, 1988, pg. 660):
  - (1) Select a present task for methods improvement.
  - (2) Flow-chart the present method or synthesize a flow chart for a new task.
  - (3) Apply principles of motion economy, etc. to arrive at an alternative method, and flow-chart this method.

- (4) Evaluate the new method via savings in cost, time, effort, storage, delays, transportation, transportation distances, etc.
- (5) Choose best method.
- (6) Implement and measure results. If results are unsatisfactory, repeat the study.

### **6.2 System Structure and Flow Analysis**

PERT analysis. Figure 6-1 depicts a network representation of interdependent activities in an example system. Since the objective of the analysis is to reduce completion time of the pipeline, a sound approach is to concentrate on the critical operation path for each of the constituent members of the pipeline. This will result in alleviating bottlenecks in the pipeline.

Production planning and control (PPC) is the function of directing or regulating the movement of goods through the entire manufacturing cycle. The goal of this task is to review the operating procedures and decision criteria that regulate material flow to identify areas for improvement.

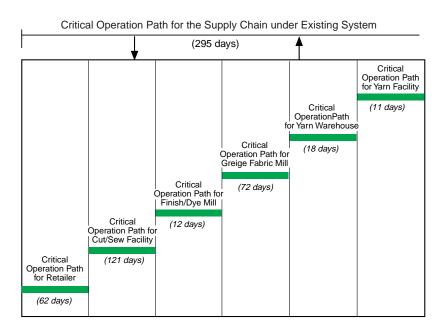


Figure 6-1. Network Diagram of Pipeline Activities.

# 7. Step 4. Requirements Met?

At this stage in the pipeline analysis process, the "as-is" system pipeline performance has been evaluated as follows:

- the pipeline has been decomposed into activities:
- these activities have been assessed for value;
- pipeline cost drivers are understood;
- goals, policies, and objectives are reviewed for consistency; and
- methods have been proposed for improvement.

If these actions satisfy the objectives as stated in the requirements document, the pipeline analysis task is complete. However, if the industry team wants to investigate how alternative scenerios in the cooperation and configuration of the pipeline perform under dynamic marketplace conditions, system performance analysis is required.

## 8. Step 5. System Performance Analysis

If the previous steps have not resulted in a solution to the problem or if the problem requires dynamic analysis for solution, then it is useful to develop a computer-based model of the system and investigate its behavior. The steps in creating and testing the simulation and evaluating the results are described below.

• Create a benchmark scenario. Use the process and information flow diagrams to create the simulation structure and objects needed to implement the benchmark scenario as a simulation model. Since the benchmark scenario is implemented within a specific simulation tool, such as Extend, Siman, SCIP, ARMS, or other tool, significant resources are typically required to create the simulation model. Some of these tools have been assessed against supply-chain evaluation criteria for the program.

- Validate the benchmark scenario. The benchmark scenario should include a set of initial conditions, a set of ending conditions, and error tolerances for the end state. This allows the simulation model to begin with the initial conditions, use the activity steps as definition of the functional transforms, and generate a set of outputs which can be compared to the ending conditions. If the simulation output is within the specified tolerances, then the simulation model can be considered to be "validated" on the benchmark scenario.
- Generate the scenario. When attempting to achieve a specific end state of a simulation, a usual process is to make repeated runs of the simulation on a basic scenario with variations in a set of parameters (often a designed experiment) in order to discover the points of leverage in the system with respect to the metrics of interest. Once a set of "improved" processes is defined, the simulation is modified, if necessary, to reflect the process changes, and the newly defined scenario is simulated to estimate its performance. Comparison of the new scenario performance with the benchmark scenario is made to assess the relative value of the improvement.
- Simulate the proposed scenarios. The simulation of a proposed scenario involves a potential modification of the simulation model so that it reflects the process definition of the scenario. Once the simulation model is verified, i.e., it captures the intent of the scenario process logic, then the input data can be entered, the simulation executed, and the associated results accumulated.
- Use sensitivity analysis. Sensitivity analysis is a tool that allows the analyst to assess the sensitivity of the simulation output to changes in the inputs. The value of sensitivity analysis is that it reveals which parameters have the potential to change the simulation outputs based on small variations in input.

- Optimize the scenario. Given a specific process definition where only the scenario inputs and parameters can be changed, optimization of the process definition with respect to an objective function is possible. One approach is response surface modeling, in which a select set of parameters are varied in order to characterize the function over the specified space of input values. Another is to use gradient methods on the input space of the simulation. The latter has several drawbacks, particularly with stochastic models, but it is useful in some cases. Other optimization techniques exist and can be applied, depending on the requirements of the analysis.
- Output the recommended scenario. The described process begins with a benchmark scenario, one that can be validated, and provides a performance baseline. Next the investigator will survey regions of the input space to characterize the performance of the simulation scenario with respect to selected metrics. Based on this information, the investigator will assess the apparent leverage points in the system. Using these leverage points, the investigator will determine if new scenarios need to be generated to achieve the analysis goals. The end result is a process description (a system definition) and a set of operating parameters that characterize process operations.

# 9. Step 6. Requirements Met?

System performance analysis is an interactive process where the scenarios of interest are analyzed and communicated to industry as they occur. Often, a scenario will uncover other potential averages to improve performance. The end goal is to use system performance analysis to assess various "to-be" configurations of the pipeline. Simply put, pipelines should be designed to produce the product the customer demands and deliver it to the right place, at the right time, at the right cost.

# **10. Step 7. Recommendations for Implementation**

Recommendations are provided to supply chain partners based upon the pipeline analysis results. The analysis can qualify the potential gains in supply-chain performance resulting from changes in pipeline processes. As a result of the review and results, the industry and analysis team can propose pilot projects to capture the improvements identified through analysis.

# 11. For Further Reading

The purpose of this guide is to provide an overview of pipeline analysis and not to go into any particular topic in great detail. This section provides a list of additional readings for many of the topics discussed in the guide.

**Activity-Based Costing** 

- Brimson, James, A., *Activity Accounting An Activity-Based Costing Approach*, J. Wiley and Sons, New York, NY, 1991.
- Cokins, Gary, Activity-Based Cost Management Making It Work: A Manager's Guide to Implementing and Sustaining an Effective ABC System, Irwin, Concord, Ontario, Canada, 1991.
- Forrest, Edward, *Activity-Based Management : A Comprehensive Implementation Guide*, McGraw Hill, New York 1996.
- Glad, Ernest, *Activity-Based Costing and Management*, John Wiley, New York, 1996.

#### Optimization

- Rao, Singiresu S., Engineering Optimization: Theory and Practice, John Wiley & Sons, New York, 1996.
- Reklaitis, G. V., *Engineering Optimization: Methods and Applications*, John Wiley & Sons, New York, 1983.

#### Simulation

- Akbay, Kunter, "Using Simulation Optimization to Find the Best Solution," *IEE Solutions*, May 1996, pp. 24-29.
- Banks, J. and Gibson, "Getting Started in Simulation Modeling," *IIE Solutions*, November 1996, pp. 34-39.
- Banks, J. and R. R. Gibson, "Selecting Simulation Software," *IIE Solutions*, May 1997, pp. 30-32. (This is a good article to start learning about simulation.)
- Burris, K.R., W.R. Oakes, and D.R. Powell, "Supply Chain Analysis Tool Evaluations." DAMA-1-5-97, May 1997.
- Chandra, Charu, A. Nastasi, D. Powell, and J. Ostic, "Enterprise Simulation Analysis of the Nylon Jacket Pipeline," Los Alamos National Laboratory report, LA-UR-97-154, 1996 (also DAMA-G-22-96).
- Fishwick, Paul A., Simulation Model Design and Execution Building Digital Worlds, Prentice-Hall, Upper Saddle River, New Jersey, 1995.
- Law, Averill M. and W. David Kelton, Simulation Modeling and Analysis, McGraw-Hill, New York, 1991.
- MacNair and Sauer, *Elements of Performance Modeling*, Prentice-Hall, Upper Saddle River, NJ, 1985.
- Massiotti, Barbara, W., "Get More Mileage from Flexible Simulation," *IIE Solutions*, May 1996, pp. 14-22.
- Swain, James, "Flexible Tools for Modeling," *OR/MS Today*, December 1993, pp. 62-78.
- Swain, James, "Simulation Survey: Tools for Process Understanding and Improvement," *OR/MS Today*, August 1995, pp. 64-79.

### Value Engineering

- Mudge, Arthur E., *Value Engineering*, McGraw-Hill, New York, 1981.
- Shillito, M. Larry and David J. Demarle, *Value: Its Measurement, Design, and Management*, Wiley-Interscience, New York, 1992.

#### **Production Operations Management**

- Chase, Richard B., Nicholas J. Aquilano, and Richard Irwin, *Production and Operations Management: Manufacturing and Services*, Irwin, Chicago, IL, 1995.
- Gaither, Norman, *Production and Operations Management*, Irwin, Chicago, IL, 1996.
- Sheridan, John H., "A Vision of Agility," *Industry Week*, March 21, 1994.

#### **PERT**

- Badiru, Adediji Bodunde, *Project Management in Manufacturing and High Technology Operations*, John Wiley & Sons, New York, 1996.
- Phillips, Joseph J., Cecil R. Davis, and Edward W. Moder, *Project Management with CPM*, *PERT and Precedence Diagramming*, Van Nostrand Reinhold, New York 1983.

#### Textile Industry

- Good, Mary L., "The U.S. Textile Industry Outlook: Competiveness and Technology Challenge," presented at the 5th Annual NTC Forum, Myrtle Beach, SC, January 30, 1997.
- Hudson, P.B., A.C. Dapp, D. Kness, *Joseph's Introductory Textile Science*, 6th ed., Harcourt Bruce Jovanovich College Publications, New York, 1993.
- Hunter, N. Alan, Quick Response in Apparel Manufacturing, The Textile Institute, Manchester, UK, 1990.

• Oakes, W.R., D.R. Powell, J.W. Jackson, J.H. Fasel, J.K. Ostic, and K.R. Burris, "An Evaluation Framework for Supply Chain Analysis Methods and Tools," DAMA I-1-97, 1997.

#### 12. References

Porter, Michael, *Competitive Advantage*, Free Press, New York, NY, 1985.

Schonberger, R. J. and E. M. Knod, *Operations Management - Serving the Customer*, Business Publications, Inc., Plano, Texas, 1988.

# 13. Glossary of Terms

Lead time - Usually, it is narrowly defined as the time from when a member in the pipeline places an order to when the goods are received. However in the context of this study, it is the same as throughput time.

Stock keeping unit (SKU) - The basic category of a stock item that has particular characteristics such as shape, size, color, material, etc., that is kept track of for inventory management.

Throughput time - The total time the initial raw materials remain in the pipeline, process or activity.

